

MANIPULATIONS IN THE SCIENTIFIC ARTS.

96.3

ELECTROTYPE MANIPULATION:

PART II.

BEING

THE THEORY, AND PLAIN INSTRUCTIONS

IN THE ART OF

WORKING IN METALS,

BY PRECIPITATING THEM FROM THEIR SOLUTIONS,

THROUGH THE AGENCY OF

GALVANIC OR VOLTAIC ELECTRICITY.

BY

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THE ELECTRICAL MAGAZINE, KEMTZ'S METEOROLOGY, &c. &c.
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RAILWAY COMPANY.

Illustrated by Woodcuts.

THIRTEENTH EDITION.

LONDON:

PUBLISHED BY GEORGE KNIGHT AND SONS,
MANUFACTURERS OF CHEMICAL APPARATUS AND
PHILOSOPHICAL INSTRUMENTS,
FOSTER-LANE, CHEAPSIDE.

Price One Shilling.

3) Nitrate of Silver crystals } Chloride
95 Solution of Common Salt } of Silver.
make

Yellow Prussiate of Potash 1803

Dissolved in water 4 pints
and with Chloride of Silver granular
in a clean tin or copper, newly tinned.
Shake & decant or let it settle & pour off
This is the Silver bath

Preparing liquor.

Solution of Nitrate of mercury & water.

○ ^{mercuric} Nitric acid enough to dissolve
water 1 to make 203.

when used I can wash with solution of Potash

2 (96.3)
ELECTROTYPE MANIPULATION:

PART II.

CONTAINING
THE THEORY AND PLAIN INSTRUCTIONS
IN THE ARTS OF
ELECTRO-PLATING, ELECTRO-GILDING,
AND
ELECTRO-ETCHING;
WITH AN ACCOUNT OF
THE MODE OF DEPOSITING METALLIC OXIDES,
AND OF THE SEVERAL
APPLICATIONS OF ELECTROTYPE IN THE ARTS.

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ELECTROTYPE MANIPULATION.

PART II.

I. INTRODUCTORY OBSERVATIONS.

92. Having in PART I. given the mode of working in copper, we pass on now to other metals. First in importance come gold and silver. The earliest experiments in electro-gilding were those by Brugnatelli, who gilded silver medals by electricity, in 1805; he used a solution of nitro-muriate of gold mixed with a solution of ammonia. The next were those of De la Rive, in 1841, who used a solution of chloride of gold. But these processes were interesting rather in a theoretical than in a practical point of view; inasmuch as the elective chemical affinity of the elements (combined in these solutions with the gold) for the baser metals, which might be immersed in the solutions, is such, that a violent interchange of elements takes place, and the gold is set free without even electric agency; and the solutions are so readily decomposed by the smallest adventitious aid, that it is a practical impossibility to obtain a "reguline" deposit, however much the voltaic power may be modified.

The following are illustrations of the deposition of gold and silver by the mere elective affinity of ordinary chemical action. If an aqueous solution of chloride of gold is agitated with ether, the chloride leaves the

water to combine with the ether, and the resulting compound, being lighter than water, floats on the surface. If pieces of polished steel are dipped into this preparation they acquire a coat of gold by ordinary chemical interchange.—If a design is traced with solution of chloride of gold upon a silk or linen fabric, and the fabric, while the traces are still moist, be exposed to a stream of hydrogen gas (which may readily be obtained by acting upon iron nails by diluted sulphuric acid), the metal is reduced, and a golden design is the result.—If a plaster cast is saturated with a solution of nitrate of silver, and placed under a bell-glass, and we admit to it the gas produced by heating a few grains of phosphorus with alcohol and a small quantity of potash, the silver will be reduced upon the surface.—If the plaster cast is made with sour whey instead of water, and is saturated with silver solution, the silver is reduced by mere exposure to sunlight, and forms, according to Elsren, a good conducting surface, in which we can deposit copper or silver according to the usual modes.

The same observations apply to the ordinary salts of silver, as, for example, the nitrate, &c. In fact, long before the theory of chemical deposits was understood, I made some experiments upon the electrolysis of this salt, and succeeded in producing an electrotype medal with a *silver* surface, being I think the *first* instance of electro-plating, when the *object of the experiment was electro-plating*. But I was unsuccessful in my attempts to repeat the experiments; and simply because, in that instance, I *chanced* to have in action a power nicely *balanced* with the work to be performed, but in future instances my power was not adjusted to the work.

93. The first practical process for working in these noble metals, is, undoubtedly, due to the patentees, Messrs. Elkington. Others have laid claim to having been the first to use solutions similar to theirs; but

whatever may have been done by these others in private, it does not appear that the public were in possession of their processes by any authentic publication; and therefore, there is no alternative but to give the patentees the claim of originality and priority.

94. The solutions they employ are the *argento-cyanide* and the *auro-cyanide* of potassium; upon which compounds it will be well if we make a few observations here, at the outset. They are what the chemists term double salts, as for instance, *cyanide of potassium* is a compound simply of potassium and cyanogen; *argento-cyanide of potassium* is silver and cyanogen combined with potassium and cyanogen, or, which amounts to the same thing, cyanide of silver united with cyanide of potassium.

When viewing (§ 13.) what happened during the decomposition of sulphate of copper, we had occasion to describe that body as *oxide of copper*, dissolved in, or combined with *sulphuric acid*: now, oxide of copper is 1 part copper + 1 part oxygen, and sulphuric acid is 1 part sulphur + 3 parts oxygen, and a certain quantity of water; so that, altogether, the arrangement is somewhat complex. This is not so much the case with the bodies now in question. And first, in respect to the simple *cyanide of potassium*, before it is united with the gold or silver. It consists simply of one equivalent of the metal potassium, and one equivalent of cyanogen; and, when it is acted upon by a voltaic current, in the usual way, it appears to be decomposed by *direct* action, and cyanogen is liberated at the one pole, and potassium is *determined* to the other, but not *liberated*. It will be remembered (§ 13.) that, in the solution of sulphate of copper, *water* was decomposed by the *direct* action, and that the copper was liberated by a *secondary* action, namely, by the hydrogen of the water returning back into solution in the place of the copper. Well; the cyanide of potassium is decom-

posed by *direct* action, and potassium is presented to the negative metal; but a *secondary* action now occurs: so great is the affinity of potassium for oxygen, that it cannot exist in a metallic form in presence of that element; as is well known from the common experiment of dropping a piece of potassium upon water, when it combines so violently with the oxygen as to produce heat and light; and the resulting products are oxide of potassium, the common *caustic potash*, accompanied with a liberation of hydrogen. So, also, in the present case; the potassium does not itself appear, but, in its place, we find hydrogen and potash; it takes oxygen from the water and forms potash, and sets the hydrogen free. It is true, we are in possession of a means of preventing its return into solution, and this is by employing a mass of mercury to receive it: in which case it unites with the mercury and forms the amalgam of potassium; and neither hydrogen nor potash are manifested; but it will remain thus only under favourable circumstances; for if the connections with the battery are broken, so that the mercury ceases to be negatively electrified, the potassium immediately leaves it, and decomposes the water as before. Thus much in reference to the simple cyanide of potassium. Of the double cyanides, the argento may be taken as an example. It consists of 1 part cyanide of potassium and 1 part cyanide of silver,—the latter cyanide, like the former, consisting of 1 part metal + 1 cyanogen. When a solution of this double cyanide is electrolyzed, silver appears at one pole, and cyanogen at the other. But, in order to the production of this result, it is absolutely essential that there be a considerable surplus quantity of the cyanide of potassium in solution; indeed, it is pretty evident that the direct action is the decomposition of the surplus cyanide, and that the silver is reduced by secondary action in the following way. When the metal potassium is reduced from its cyanide, it returns

into solution, and takes the place of the silver in the double salt, setting the latter metal free; so that, while on the one hand an equivalent of simple cyanide is consumed, on the other hand an equivalent is formed, and the equivalent previously engaged to form with the silver the double salt, is also free; and thus far there is an increase in the quantity of simple cyanide of potassium. But, if the positive metal is silver, the cyanogen combines with it and forms cyanide of silver; for cyanogen is a gas, and like oxygen seems to combine with metals in this its nascent state; though, unlike oxygen, it is a compound body, consisting of 2 equivalents of carbon + 1 of nitrogen, whence it is also termed bi-carburet of nitrogen. Well: cyanide of silver is insoluble in water, and hence would form an insulating crust on the silver plate were it not for the presence of cyanide of potassium in excess in solution; it readily dissolves in this, and so keeps up the strength of the solution; and the extra element of cyanide of potassium, mentioned above, is thus neutralized.

Having thus described the general character of the cyanide solution, it remains for us to give the processes by which the several elements are most favourably brought together.

95. *Cyanide of Potassium*.—To obtain this, we set out with the ferro-cyanuret of potassium, or yellow prussiate of potash of commerce; and as this prussiate is readily accessible at all chemists', it is better in general to purchase than to make it; the mode by which it is obtained will be found in any treatise on chemistry. It consists of 1 equivalent of cyanide of iron + 2 equivalents of cyanide of potassium. It is of a bright yellow colour, and is converted into the colourless simple cyanuret in the following manner:—Take 4 oz. of the yellow prussiate, break it in small pieces, and dry it well on a plate of iron; then reduce it in a mortar to exceedingly fine powder. Dry and

pound in like manner $1\frac{1}{2}$ oz. of carbonate of potash. Incorporate the two ingredients thoroughly. Place a Hessian crucible in the fire; and when it attains a red heat, throw into it the prepared mixture, and closely cover the crucible. Keep up the heat, and the contents of the crucible will soon fuse, and the fluid mass will become red-hot. After this, immerse in it, from time to time, a hot glass rod; the mass, that adheres to the rod in the early stages of the process, is brown on cooling; as the heat is continued, it appears yellowish, and finally, colourless and transparent. The operation is then complete: the crucible must be removed; and after its contents have been allowed to settle, the fused mass may be poured off: the greater portion of which consists of the *simple cyanuret of potassium*.* The impurities contained in this product are not detrimental to its use, in a general way, for the purposes in view; however, in cases where it is required pure, it must be boiled in strong alcohol; and when the alcohol cools, the pure cyanide will be deposited in the form of small white crystals. This salt is very deliquescent, and must therefore be retained in close bottles; it will readily be recognised by its powerful odour,—similar to that produced by peach blossoms. The mere mention of *prussic acid* almost entering into its composition, will be sufficient to induce my readers to exercise common caution in handling it.—A solvent solution is prepared by adding two ounces of this salt to a pint of rain, or of distilled water; when the salt is well dissolved, the liquid is ready for use.

96. *Silver Solution*.—Silver may be presented to the above solution in various forms; as the oxide, the chloride, the carbonate, the nitrate, &c.: solution will in either case occur; and the double cyanide of silver and potassium will be produced. But since the silver, as we hinted before, must become a cyanide of silver,

* This method was first described by Messrs. Rodgers, in the *Philosophical Magazine* for Feb. 1834; and since by Prof. Liebig.

before it can thus unite with the cyanide of potassium, it is obvious that one portion of the solution must give up its cyanogen to the silver, and take to itself the bodies previously in combination with that metal. So that, from the oxide of silver, potash would occur in the solution ; from chloride, chloride of potassa ; from carbonate, carbonate of potassa ; and from nitrate, saltpetre. Of these, the least likely to interfere with this general action is the potash ; and hence, oxide of silver has been frequently used. It is thus prepared :—

97. *Oxide of Silver*.—Place pieces of silver in a glass vessel, and pour on them about equal parts of water and strong nitric acid ; the metal will soon dissolve, giving off fumes of nitric oxide. Should the solution have a green hue, which is invariably the case, unless the metal has been obtained fine from the refiners, it indicates the presence of copper ; in which case immerse some pieces of copper in the solution, and the nitric acid, by elective affinity, will combine with the copper ; and a precipitate of pure silver, in the form of a greyish powder, will take place. Throw away the liquid, and wash the silver precipitate several times in sulphuric acid and water, and afterwards in water alone. Then re-dissolve it, as before, in nitric acid and water ; and a *solution of pure nitrate of silver* will be obtained. Place this in an evaporating dish, or a saucer, and apply the heat of a spirit-lamp, or place the saucer by the fire-side, till some portion of the liquid is driven off in vapour. Allow the residue to cool, and it will shoot out into long colourless transparent crystals, which are *nitrate of silver*. They must be handled with care, as they possess the property of staining animal and vegetable substances with an almost indelible black ; fused nitrate of silver being the lunar caustic of surgery, and the main ingredient also of marking ink.—Next prepare some *lime-water*, by stirring lime into water, and filtering the solution.

As lime is very sparingly soluble in water, requiring, at 60° Fahrenheit, 750 times its weight, it is necessary to make an abundant supply. Place the lime-water in a glass or other vessel, and drop in it a *few* crystals of nitrate of silver: the colourless solution will instantly assume an unsightly brown hue; and, after remaining quiescent for a time, the *oxide of silver* will subside in the form of a dark brown precipitate. The liquid is then poured off, and the precipitate is washed with water. Before throwing away the liquid, fresh lime-water should be added to it; and if the dark hue recurs, the precipitate must be allowed to subside again: if no change takes place, it may be inferred that the silver is all extracted. The oxide of silver should not be dried; but be kept in bottles with water. A quarter of an ounce of oxide of silver, added to a pint of the solvent solution, forms a very useful plating solution.

98. *Cyanide of Silver*.—But as the above solution is impure, in that it contains as much potash as is equivalent to the oxide of silver added, it may not be applicable to accurate experiments; and as the potash is produced, in the formation of cyanide of silver, at the expense of a certain portion of the cyanide of potassium, it is a wise plan, for it is no more costly, to form the cyanide of silver in a separate vessel, and to wash away the impurities before adding it to the solvent. Take then a neutral solution of nitrate of silver; add carefully a solution of cyanide of potassium, when a white precipitate of cyanide of silver will fall; continue adding until precipitation ceases. The liquid, which is a solution of nitrate of potash or saltpetre, is to be poured off, and the precipitate well washed. It will be pure cyanide of silver, if the materials employed were pure; and it is now fit to be added to the solvent liquid, to form a plating solution free from impurities.

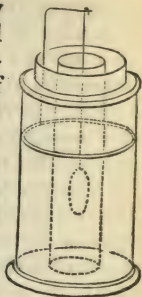
99. *Preparation of the Gold Solution*.—Warm a

pint of pure rain or distilled water, and dissolve in it two ounces of cyanide of potassium as before; then add a quarter of an ounce of oxide of gold. The solution will at first be yellowish, but will soon subside to colourless transparency. Those not versed in chemical manipulation will be wiser to purchase than to prepare oxide of gold; but, for general information, I give the process:—Dissolve pure gold in two measures of muriatic with one of nitric acid; evaporate to dryness; dissolve the residuum in twelve times its weight of water; add to this a solution of pure carbonate of potash, dissolved in twice its weight of water; apply a moderate heat, about 170° , and a reddish yellow precipitate occurs. This is the *hydrated* per-oxide of gold. Wash it well; and, to render it anhydrous, boil it in water. It then assumes a brownish-black colour, which is the oxide required.

100. I by no means give these as *standard* proportions of the several ingredients required. They are the proportions which I employed with success in gilding and plating the series of metals (submitted to the Electrical Society at their meeting, Sept. 21, 1841), by the battery process to be hereafter described. When the same object is effected by the employment of a single cell, it will be requisite to alter the degree of saturation according to circumstances; to which, however, I shall have further to allude in the sequel.

101. *Single cell for plating and gilding.*—The necessity of economising solutions of such value as these, has led to certain modifications in the apparatus, contributing to that end. The porous cell, (§ 17.) which in other arrangements contains the zinc and acid, and is surrounded by the copper or other negative element, in the present process contains the *cyanide solution*, and the negative element or object to receive the deposit, and is surrounded by the zinc, &c.

102. This arrangement will be readily understood by a glance at the annexed woodcut, which represents a porcelain cell containing a cylinder of zinc; and an inner porous tube filled with the solution of silver or gold. Connection is made between the zinc and medal or mould by a binding screw; or by mere contact, as in the figure.

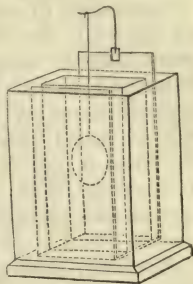


103. I must again dwell upon the philosophy of the action of this arrangement, and return to first principles, in order to impress them more firmly on the minds of those who read these pages with the intent to repeat the experiments. For it is a matter of some importance, in employing the costly salts of the noble metals, to have the principles of the experiment traced out as distinctly as possible.

104. In the arrangement just described, the nature of the deposit will depend upon the principles elsewhere (§ 78.) set forth; and *à fortiori*, from the facility with which the salts of silver or gold are decomposed, there will be a much *greater* chance of releasing hydrogen, and spoiling the experiment; to prevent which, therefore, ample provision must be made. For instance, if the silver solution is *weak* in proportion to the *energy* of action between the zinc and acid water, the electricity developed will be *more* than sufficient to release pure metal, and hydrogen will be evolved, the result being a deposition of oxide. Or, if the balance between the strength of the solutions be duly adjusted, the relation between the size of the zinc and of the medal or mould may be such as to determine the same result. It is therefore requisite that the water which excites the zinc, should contain *very little acid*,—a few drops, more or less in proportion as the cyanide solution contains more or

less of the oxide; and that the strength of the latter should be maintained by a fresh supply of oxide from time to time.

105. Another and, in some cases, more convenient form for the single-cell apparatus is given in the annexed woodcut; in principle it differs nothing from the former; the porous cell to contain the cyanide solution being flat, affords the means of immersing a larger medal, without an extravagant supply of liquid. The zinc which envelopes the porous cell is also flat. The connections are made as before.



106. *Plating by means of a single cell.*—Having charged either of these arrangements with the weak acid water and the solution of silver, let it remain for a few minutes; in order that the porous cell may be moistened through, and that action may commence as soon as the circuit is completed. Then attach a *thin*,* pliable wire to the medal or mould, and place its other end in contact with the wire attached to the zinc: complete the circuit by immersing the metal in the silver solution, and a deposition will *instantly* take place. It will present a *dead* whitish appearance.—At the meeting of the British Association in Birmingham, in 1849, Mr. Elkington stated, “that a few drops of the sulphuret of carbon, added to the cyanide of silver in the decomposing cell, had the property of precipitating the silver perfectly bright, instead of being granulated so dead as it is when thrown down from the solutions ordinarily employed.”

107. Should the silver deposit present a whitish

* This principle, so often alluded to, of retarding or restraining the energy of the action, is regarded in the employment of *thin* wire; it is a very valuable adjunct to the other means (§ 78) of obtaining the same end; and may often be adopted with advantage.

surface, streaked with perpendicular *black* lines, it may be regarded as an indication that the action is attended with a development of hydrogen : this must be prevented by some of the means so often mentioned. (§ 78, &c.) By careful attention at the commencement of the process the right degree of action is readily obtained ; and if the process is continued (with occasional watching) for about half an hour, the medal will be beautifully coated with *dead* silver. In that condition it may remain, after being washed, and dried in blotting paper. Or, if a burnish is desired, the leather and plate-brush must be used ; or it may be thrown down bright as above (§ 106).

Mr. Bain has patented an instrument, which he styles a “ Voltaic Governor.” The plates of the voltaic arrangement are immersed to a depth sufficient to produce the electricity required. They are suspended in the liquid as weights to a clock-work arrangement. When the action diminishes, a keeper from an electro-magnet, through which the current passes, is moved, and the plates are said to sink until enough of electricity is generated to cause the electro-magnet again to attract the keeper.*

If, instead of plating medals, the object is to deposit silver in a mould, as mentioned elsewhere, the same preparations are to be made ; but the mould should be allowed to remain for some minutes (more or less according to the thickness required) subject to the action of the current. It may then be removed, and after being washed with water, and afterwards with water containing a few drops of nitric acid, may be placed with proper connections in a copper solution, (§ 57.) to remain there till it is sufficiently backed up with this metal.

108. *Gilding by means of a single cell.*—The operation of gilding is conducted much in the same manner as that of plating,—gilding, however, re-

* *Vide* Mech. Mag., 5th Aug. 1843.

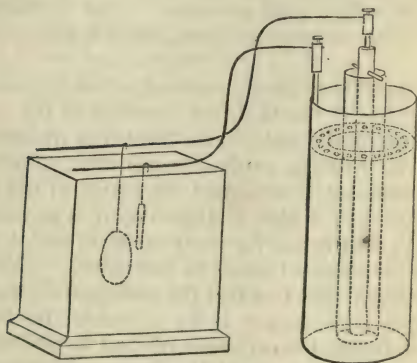
quiring a little longer time, and occasionally hot solutions.

109. The operations of gilding and plating seem at first to have been very generally effected by means of the single cell, in a manner more or less in accordance with the directions I have just given, as the nature of the case permitted. In fact, *plating* by this process had been adopted on a scale of some magnitude in the great manufacturing town of England; the strength of the solution being maintained by fresh supplies of the oxide of either gold or silver. And if attention be paid to the instructions given, there is little fear of failing.

110. Before describing a method which appears far superior to this, I would direct attention to the source whence the silver and gold, in the single cell process, are obtained, viz. from the *oxides*, for instance. For every ounce of these metals deposited, a quantity of the oxide must be furnished, which shall contain in it an ounce of *pure* metal; and hence for every ounce of *metal*, much *more* than an ounce of *oxide* is consumed. The time and trouble required to effect the combination between these metals and oxygen is by no means inconsiderable; and hence the expense of first producing the oxide of gold or silver and then releasing either from the after-combination with cyanogen, far exceeds the actual cost of the metal employed: *how* far depends upon circumstances. The object, however, may be accomplished with far more certainty, and at considerably less expense by means of an additional cell, (§ 56.) and a plate or wire, &c. of gold or silver, to keep up the strength of the solution, as in the case of sulphate of copper. This method is now adopted generally by the several patentees; for experiments with solutions of silver and gold in union with cyanogen, have shown that *cyanogen nascent at the positive plate in a decomposition cell will combine with silver and also with gold*. This furnishes a

means of gilding and plating, by the use of a generating cell to furnish the electricity, and a decomposition cell to contain the cyanide solution; the nature of the changes produced has already (§ 94,) been described.

111. *Battery process for plating and gilding.*—The generating cell for acting upon solutions of silver need not be large. A pint Daniell, similar to that in the woodcut, or a series of two, is sufficient for



larger medals than can be placed in the decomposition cell attached. The latter is of porcelain or glass. Of course, the size varies according to the extent of the experiment. The zinc may be used unamalgamated, and excited with salt and water; the copper cell, of the Daniell's battery contains, as usual, a solution of the sulphate. (§ 57.) Gilding may be better accomplished by using three cells of Daniell's battery.

112. *Voltaic Condenser.*—Prof. De la Rive has introduced an instrument, which he has named the *Voltaic Condenser*,* and which may probably be of some service in electro gilding and plating. Its property is

* Vide *Arch de l'Elect.* No. 8. p. 173, and *Elec. Mag.* p. 38.

to give to one cell of a battery the intensity of two or three, being the power required for these processes; and it does this at the expense of only *one* equivalent of zinc. It is well known to electricians that at the moment contact is made with a battery, so as to send a voltaic current along a wire in one direction, a *secondary current*, which endures but for an instant, is induced in the wire in the reverse direction; and when contact is broken, so that the original current ceases, the secondary current is induced to move in the direction contrary to its original motion; and therefore in the *same* direction as that pursued by the primary current, when contact was first made. The intensity of this current greatly depends on the quantity, the character, and the form of the wire employed; and if the wire is coated with silk and wound round a bobbin, the intensity is greatly increased;—M. De la Rive uses 100 convolutions of three stout copper wires, and places within the coil a bar of soft iron, the use of which will soon become evident. The object of the arrangement is to convey the battery current, and with it the secondary current through the solution to be decomposed.

113. For example, we will select the gold solution to illustrate the use of the *condenser*. Metallic connections are applied between the ends of the coil and the two terminations of a Daniell's or Smee's battery. The connections are continued to a vessel containing the gold solution, the arrangement being somewhat like the figure ∞ , where the generating cell is to the right, the coil in the centre, and the decomposition cell to the left. The current, on leaving the battery, has thus the choice of two paths, the one being through the coil, the other through the solution; but from the great comparative resistance of liquids, compared with metals, far the larger portion would pass through the coil, while a comparatively small share would traverse the solution of gold. In passing through the coil, how-

ever, it converts the soft iron core into a magnet ; this magnet instantly attracts a piece of iron, which is so arranged that, on being raised, it removes a wire and thus breaks off communication between the coil and the generating cell, except by means of the cell containing the solution. The current therefore now passes through the gold solution. But when the coil ceased to be alone in the circuit, a secondary current was induced in the same direction as the original battery current ; this, therefore, joins with the said generating current, and *both pass together* through the gold solution ; by which means the actual power of the battery is very greatly exalted. Now, the iron core loses most of its magnetism, as soon as the liquid is included in the circuit ; and hence the piece of iron, the raising of which broke contact, falls again, and the coil is again included, when the same phenomena recur ; and thus, by a continued succession of breaking and making contact, the *current of a moment*, namely, the *secondary current*, is created, and employed with very great advantages. My readers must be content with this general description ; and I must trust to their own ingenuity for making arrangements agreeable to these directions.

114. *Application of Heat*.—Considerable advantage accrues in all cases of the deposition of metals where adhesion is desired, by the use of heat. It expands the baser metal, and so far opens its pores, that the subsequent contraction, consequent on the effect of common temperatures, is likely to operate favourably in binding the metals together. It has other advantages, especially in gilding. The mode of heating the solutions will depend entirely on the circumstances under which the experiments are conducted. If a hot stove, or a sand-bath be at hand, the object is soon accomplished ; but, in most cases, a simple plan is to use a lamp and a glass or other retort, and convey steam by a glass tube into the metallic solution, either of the single

cell apparatus, or that contained in the decomposition cell.

115. With regard to the time requisite for plating and gilding, it is entirely dependent on the nature and uses of the article. The thickness of the deposit, of course, depends on the duration of the action. For medals, and such things as are not exposed to wear, a few minutes' immersion may be enough; for spoons, forks, plated goods, &c., subject to much wear, six or eight, or even more hours; always taking care to watch the process at times, in order to prevent the occurrence of the black lines; whenever they appear, the action must be retarded. Large objects, or those which are subject to a long action, should be occasionally withdrawn, and their position should be altered; so that a uniformity of deposit may occur. *Motion* of the articles during the process has been recommended, and with some show of reason. The readiest method of producing it is to suspend the article in the solution from a common bottle-jack, and connect the latter with the battery. Or, on the large scale, when it would not be convenient to have a roasting-jack for each group of articles, it might be convenient to have a constant flow of the solution. The surface obtained in the deposition of silver by Electrolysis is technically termed "dead." Medals thus coated, if care be exercised during the operation, are very beautiful, and should be prepared for the cabinet by simply washing in water. If a bright surface is desired, they are polished with a leather and plate powder. (§107.) Ordinary plated goods are finished off by polishing and burnishing. A steel or agate burnisher is used. In articles of jewellery some parts are left dead, and others are made bright.

116. *Preparing surfaces to unite with gold and silver.*—But we are going on too fast; I must return to certain things preliminary to plating and gilding, which I had passed over, in order not to interrupt the

progressive illustrations of the nature and preparation of the solutions. I allude to the preparation of the surfaces, previous to applying the metals; which is a point of such paramount importance that, unless duly regarded, all subsequent operations will be futile; and it would be in vain to hope for perfect adhesion between the metallic base and the deposit; the latter will rise up in blisters where the surface is not properly prepared, and can easily be rubbed off.

117.—There are two methods of preparing metals for the reception of other metals,—the wet way, and the dry way. The experiments of M. Becquérel and others, are decidedly in favour of the latter; but as it cannot be adopted, except in certain cases, where the work of the article is plain and the article itself is not delicate, it will be necessary to describe both modes. The main intent of cleansing is that the contact between the two metals may be perfect; and it effects this by removing grease and all extraneous matter, especially the oxides, which are ever found on the surface of the less noble metals.

118. *Cleansing by the dry method.*—The advantage of the dry process over any in which moisture has been employed, is that, in the latter case, several seconds, at least, must always pass between the act of removing the article from its last liquid bath, and placing it in the solution of the metal to be deposited; and during this short interval, the article, or some portion of it, very frequently undergoes an alteration, trivial indeed, but still an alteration, by the action of the air, which produces a film of oxide, infinitely thin, it is true, yet quite enough to militate against the success of the experiment, as regards permanent adhesion. Therefore, wherever the dry process can be adopted, it is decidedly the better; although, from the very nature of the articles subjected to the process, the number of cases in which it is available is very limited. The dry process is merely the operation of scouring with sand, or

glass, or emery paper, as the case may be, or with very fine powder of pumice stone; using clean brushes, utterly free from grease. Sometimes fine files may be used; indeed all depends on the value and character of the article operated upon. It must be remembered throughout that grease and oxide are the great enemies to be expelled; and therefore, especial care must be taken to avoid contact with the moisture of the hand, which is of a nature to produce either.

119. *Cleansing by the wet method.*—The solutions employed may be divided generally into two classes, the acid, and the alkaline; the action of the former is directed more towards the removal of oxides, &c.; that of the latter to the removal of grease. As a rule, I would always follow the use of an acid bath by an alkaline, having first washed away the acid in several waters; and this may be done, whether the operation commence with an alkaline bath or not. The following are some of the modes in use; they are all effectual according to the circumstances which give preference to one over the other:—The method recommended by M. Boettiger in his account of gilding, given in the *Annalen der Chemie und der Pharmacie*,* may be adopted. He says, “it is very necessary to rub the metal according to circumstances,† with extremely fine sand, moistened with hydrochloric acid mixed with a little chalk, so that there shall remain no trace of oxide of copper.” Another effectual method is immersing the article in a mixture technically termed “pickle.” This may be made of

Sulphuric acid	64 parts.
Water	64 „
Nitric acid	32 „
Muriatic	1 „

The “pickle” is used by tying a wire round the article

* Vol. xxxv. p. 350.

† i. e. when it can be done without injury to the object of experiment; and this, too, must be the guide in the application of the other modes.

and immersing it for a second or two; the action is very energetic, and, of course, is not suited to the preparation of medals:—for medals, the mixture should be very much diluted, and they should remain in it for a short time. A mere bath of dilute nitric acid is often used. Nitric acid, mixed with sea-salt and soot, is often rubbed on the article. Concentrated sulphuric acid and sea-salt is another mode.—Of the alkaline solutions are caustic soda, or solution of soda and ammonia, or caustic soda and sal ammoniac; or the articles may be boiled in a solution of common soda or potash, which is a very good method of cleansing them.

120. Whatever solution is used, whether acid or alkaline, or the detergent paste of soot, or chalk and acid, fresh water must not be spared for rinsing off all remaining traces; and the article must be dried for immediate use by pouring over it *boiling* distilled, or rain water; or, if the process of deposition is not to be commenced immediately after the rinsing, it may be buried in hot or cold box-wood sawdust, until required; it may often be dried for immediate use in hot sawdust. In addition to the detergent methods already given, an ancillary means, which has been found effectual, depends upon the fact, that metallic and other surfaces, after exposure to the air for some hours, become coated with a film of air so intimately as to retain it, even (as in electrotype cases) between themselves and any metal deposited upon them. In fact, we have been advised, in copying large subjects by electrotype, to take advantage of this, and to allow the film to arrange itself, before the plate is submitted to the action of the battery. For it is found that the presence of this natural film very materially operates in preventing adhesion between the plates and the deposit: whereas, in the absence of the film, unless its place has been supplied by something else, other things being in order, the *two* will effectually become *one*. We are advised, too, after soldering a wire to a copper plate, to allow the latter to remain an entire

day, to regain the film of air which had been driven off by the heat. Carrying out this principle, the boiling alkaline solution and the boiling water answer a double end; and hence are very effectual means of promoting perfect union between the metals. Heat operates still more favourably in causing the expansion of the metal, as I mentioned when recommending its adoption in the process itself of electric deposition. Iron may be prepared and cleaned by electrolytic action, as described elsewhere. (§ 166.) In preparing steel for gilding it must be polished without oil, as the oily particles adhere so closely that it is scarcely attacked by strong muriatic acid.—The last cleansing method I have seen, and it is a capital one, is to scour the surface with Calais sand, moistened by the silver or gold solution, and rubbed in with a scratch brush.

121. *Amalgamation to promote adhesion.*—Another method in this preparatory stage of the proceedings, to which I shall allude, is that recommended by M. Becquérel;* and which promises to be of great avail in ensuring a successful termination to the experiment. After the articles are thoroughly cleaned, according to the instructions now laid down, they are dipped into a solution of proto-nitrate of mercury; when taken out they are washed in abundance of water; and are then rubbed with leather, in order to promote the equal spread of the mercury. These operations are repeated until the whole surface is well coated with mercury. The ultimate character of the metallic deposit depends on the surface given to the mercury; if the employment of the leather is only such as is needed to effect the more equal diffusion of the mercury, the surface is dull or dead, and so is the deposit; whereas, if brisk friction is applied, and the mercury receives a good polish, such will be the character of the metal thrown down. And thus may burnished gold or dead gold be produced at pleasure. By

* *Vide Les Comptes Rendus*, July 3, 1843.

adopting this method of giving a mercurial coat as the foundation for the plating or gilding (and it is especially valuable for the latter), a double advantage accrues; the close adherence between the metals is ensured,—and a coating of gold of any thickness may be thrown down. The mercury is subsequently driven off by heat, either heat applied for the purpose, or the heat employed in some of the operations by which the work is finished.

122. German silver is prepared by allowing it to remain for three or four hours in a cold solution of carbonate of potash. It is then washed in cold water, and dipped into dilute nitric acid. After again washing and drying it, it is rubbed with leather; and immediately before placing it in the silver solution, it is dipped into a solution of common salt, containing a little gum.

123. *Cleaning Electro-plate.*—Electro-plating, especially of dead silver, is very liable to turn yellow, after a few days' exposure to the light. M. Mourey found* that this was due to the decomposition of a cyanuret or a sub-cyanuret remaining on the silver surface on its emersion from the solution. He removes it in the following manner:—The articles are covered with a thick layer of dissolved borax, and, being placed in a muffle, are submitted to a heat somewhat below cherry-red, which is sufficient to calcine the borax. They are then thrown into water acidulated with sulphuric acid, and allowed to remain. After being withdrawn from this, they are washed in water and dried first in hot saw-dust, and then on a stove or otherwise. The result is the production of that white colour so essentially requisite to dead silver, especially in articles of jewellery. I may add to this a process for cleaning tarnished silver in general, which, though not much known here, is practised constantly by the natives in India. A few tamarinds are placed in water contained

* Vide "Comptes Rendus," April 3, 1843. p. 660.

in an earthen vessel, and the silver articles are boiled in it for a time, and they emerge clean and very white.

124. *Gilding-wax*.—The proper colour is given to the surface of electro-gilding by covering it with *gilding-wax*, and heating it till the mass begins to smoke. Gilding wax consists of the powders of salt-petre, sal-ammoniac, sulphate of iron and verdigris mixed with melted wax. This operation removes the brassy appearance, which the surface often presents, and gives the rich gold colour, on which the beauty of the work depends.

125. *Various metallic solutions*.—M. Louyet has used with great success a solution of bi-sulphuret of gold in cyanuret of potassium. This solution is neutral to silver, copper and brass, so that no action occurs on the surface of these metals until the circuit is completed. The bi-sulphuret of gold is prepared by passing sulphuretted hydrogen through a solution of bi-chloride of gold; or by pouring into such solution hydro-sulphate of ammonia. The bi-sulphuret is collected in a filter, where it must be well washed with *warm not boiling* water: it is then dissolved by pouring the cyanuret solution (§ 95.) through the filter. The solution has a clear gold colour; it is diluted for use to a pale straw colour.

126. M. Becquerel has introduced a very philosophical mode of gilding by the single cell process. A solution was made of 1 gramme of dry chloride of gold, 10 of ferro-cyanuret of potassium* and 100 of water; it was filtered, and to it were added 100 grammes of a saturated solution of yellow ferro-cyanuret of potassium:—The solution was used in that state, or diluted with once or twice its bulk of water according to the character of surface desired. This solution is placed in the porous tube of a single cell, (§ 18.) and into the cell surrounding the zinc is poured a solution of a similar character with the exception that

* The prussiate of potash of commerce.

it *does not contain any gold*; but, in lieu thereof, it contains a little common salt. Unamalgamated zinc is used.

127. There is not space to give detailed accounts of the many other solutions that have been used; let it suffice to mention in brief a few:—

M. de Ruolz has employed,

1. Cyanuret of gold, dissolved in simple cyanuret of potassium;
2. Cyanuret of gold, dissolved in the yellow ferro-cyanuret;
3. Cyanuret of gold, dissolved in the red ferro-cyanuret of potassium.
4. Chloride of gold dissolved in the same cyanurets;
5. Double chloride of gold and potassium dissolved in the cyanuret of potassium;
6. Double chloride of gold and sodium dissolved in soda;*
7. *Sulphuret of gold dissolved in neutral sulphuret of potassium.*

The latter is said to be singularly valuable.

He uses cyanuret of silver in yellow ferro-cyanuret of potash. Where 6 cells in series are required for gilding, 4 are sufficient for plating.

128. He effects *platinating* with the double chloride of platinum and potassium in caustic potash, with the same ease and facility as plating and gilding; but when he used cyanuret solutions of platinum, like those of gold or silver, it required one or two hundred times the duration of the experiment to produce a corresponding result.

Lead is precipitated from oxide of lead dissolved in potash.

Tin is deposited on iron and zinc, &c., from a solution of oxide of tin in potash, or tin in cream of tartar; which latter is the solution employed for tinning pins, the process being in truth an electrical one; for the

* The analogous salt of potash does not succeed.

pins and the tin are thrown into the liquid, where the latter receive a coating.

Zinc is deposited, especially on iron; the solution is not named.* Elkington's solution for zincing is given in the sequel. (§ 138.)

129. M. Boettiger uses for *gilding* one part of chloride of gold, as neutral as possible, and 100 parts water, in which he allows the action to be repeated about half-a-dozen times, of a minute's duration each, and washes the article between each operation with fine linen in pure water. For *platinating* he has a corresponding solution of platinum. He has also employed one part of chloride of platinum, 100 parts water, and 8 parts hydrochlorate of soda; or one part ammoniacal chloride of platinum, dissolved, with 8 parts of sal-ammoniac, in 32 or 40 parts of water. The latter solutions are used without the voltaic current to give a thin coating; which may doubtless be increased by the voltaic action.

130. Mr. Woolrich uses the following solutions: -

He first prepares what he terms the solvent, or sulphite of potash, thus:—28 lbs. of the best pearl-ash, and 30 lbs. of water are boiled in an iron vessel: the solution is allowed to cool, and is then filtered. To this are added 14 lbs. of distilled water; sulphurous acid gas† is then passed into the liquor until it becomes saturated; and the liquor is filtered for use.

Silvering-liquor.—12 oz. of crystallized nitrate of silver are dissolved in 3 lbs. of distilled water. The solvent just described is gradually added, so long as a whitish precipitate falls. The supernatant liquor is poured off, and the precipitate washed with distilled water. To the washed precipitate is added as much of

* *Vide* Les Archives, June 7, 1842.

† This gas may be obtained by applying heat to a flask containing sulphuric acid and pieces of well-burned charcoal. The gas should be passed through water to free it from any acid it may have carried over.

the solvent as will dissolve it; and then $\frac{1}{6}$ th part more, so that the solvent may be in excess. After being well stirred, and allowed to remain for 24 hours, the liquor is ready for use.

Gilding-liquor.—Four oz. troy of fine gold are dissolved in a mixture of 11 fluid oz. nitric acid, 13 muriatic acid, and 12 distilled water: the solution is evaporated and crystallized; and the crystals are dissolved in 1 lb. of distilled water; the gold is then precipitated by pure magnesia, the precipitate is first washed with distilled water acidulated with nitric acid, and then with water alone. To the washed precipitate is added enough solvent to dissolve it, and $\frac{1}{3}$ th more. After being stirred and remaining 24 hours, it is fit for use.

Coppering-liquor.—7 lbs. of sulphate of copper are dissolved in 30 lbs. of distilled water, and to this is added solution of carbonate of potassa until precipitation ceases. The precipitate is washed, and dissolved in the solvent as before, one-third more being added. This must stand for twenty-four hours like the others.

131. Mr. Tuck has prepared the following liquid. He dissolves 70 parts by weight of bi-carbonate of ammonia in distilled water, to which he adds by weight 56 parts of sulphate of silver, or 134 parts of cyanide of silver, and boils the liquor until the silver salt is entirely dissolved. The strongest solution that he has employed was in the proportion of half an ounce of sulphate of silver and 107 grs. of bi-carbonate of ammonia to a pint of distilled water.

132. Mr. Briant, of St. Petersburg, gives the following preparation of *gold solution*, as superior to any other. He makes a solution of $6\frac{1}{2}$ solotnik (428 grs.) of gold in *aqua regia* (nitro-muriatic acid), by aid of a sand-bath: he boils it down to one-fourth, when crystallization occurs; he evaporates, but not to dryness. The crystals are then dissolved in hot water, and half

a pound* of powdered magnesia dissolved in water is added. It is filtered warm: if the liquor is dark, the magnesia is not all dissolved, when it must be boiled again. It is now washed in the filter, and the *hydrated* oxide of gold remaining in the filter is placed in a flask, and on it is gradually poured half a Russian pound of nitric acid; after the effervescence ceases, it is again filtered and well washed; and the chocolate-coloured residuum is boiled in a hot prepared solution of 1 lb. 22 solotnik (7766 grs.) of prussiate of potash; when it boils, 10 solotnik (6.58 grs.) of caustic potash, previously dissolved in cold water, are added, and well mixed. When cool, the solution is filtered for use: the sediment now remaining in the filter is oxide of iron.

133. Major Von Jewreinoff gives the following *silver* solution:—4 parts of dry powdered prussiate of potash are well incorporated in a mortar with $1\frac{1}{2}$ parts of pure potash, and are melted in a closed vessel till the product becomes transparent and dazzling white. Chloride of silver, prepared by throwing salt into a solution of nitrate of silver, is dissolved in this solution and filtered for use.

134. A writer in the *Mechanics' Magazine*, Mr. Rockline, has used the following solution:—Oxide of silver is dissolved in citric acid; the solution is evaporated to dryness, and the residual salt is exposed in a tube to 212° Fahr., when a current of dry hydrogen is passed over it for a few minutes. The salt is then dissolved for use in *cold* water. He says this solution must not be heated.

135. *Other applications of Electro-Gilding.*—On the continent, and here also, this art has been rendered available in gilding the springs and works of chronometers; and one experimentalist, M. Perrot, has “undertaken to gild at the same time all the movements of a watch,—to gild them, not only in their places, but

* A Russian pound, of 96 solotniks, is equal to 6318.5 grs. Eng.

while in motion."* M. Boettiger, to whom I have already (§ 129.) alluded, has employed for gilding, the bi-chloride of gold, and has prepared copper surfaces, by first depositing platinum upon them. M. Hamman, an engraver of Geneva, has deposited a coat of *gold* instead of one of *varnish* on plates intended for ordinary etching, and has traced the design most accurately, through this exceedingly delicate layer.

136. Electro-gilding has been successfully applied in protecting and permanently fixing Daguerréotype pictures. It is well known that thin films of gold are transparent. A thin film is therefore deposited upon the surface of the finished plate, and effectually secures the picture from destruction ; while it does not in the least hide it from the eye, or detract from its beauty. The silver surface of Daguerréotype plates is greatly improved by depositing upon them a thin film of silver, and subsequently polishing them according to the usual plan.

137. *Daguerréotype Plates.*—The art of electroplating may be made available in preparing Daguerréotype plates. The lovers of this attractive art (which is so well explained in the third and fourth numbers of this series of Manuals,) may thus experiment upon plates of their own preparation. They may be prepared in two ways : either by plating a burnished and prepared copper plate ; or by depositing silver, with due precautions, on a burnished plate, and afterwards backing up with copper. The latter is the most effectual, especially to those who are not skilled in the plans adopted by the artizan for the treatment of burnished surfaces.

138. *Electro-zincing.*—Messrs. Elkington have patented a process for applying zinc to iron, in order to protect it from the atmosphere. They say that the best and cheapest solution is the sulphate of zinc, of which they dissolve a pound in a gallon of water ; and

* Vide Arch. de l'Electricité, No. I. p. 276.

electrolyze it with a battery of feeble power. This is not the well known *galvanized iron*. The latter is prepared by immersing the iron in melted zinc; which process gives to it a coat of the latter metal, that acts as a most valuable protection against the corrosive influences of the atmosphere, as will be seen in the fifth of these Manuals, which treats upon the "Electric Telegraph," for which it is extensively used.

139. *Reduction of alloys*.—This has been long deemed impracticable; but recent experiments have proved that it is possible. M. de Ruolz was the first to deposit a galvanic film of *bronze* on other metals, by dissolving cyanide of copper and oxide of tin, in certain proportions, in cyanide of potassium, and allowing a constant battery to act upon the solution. Professor Majocchi reports the deposition of an alloy of *lead and iron*, which he says is much harder than lead, and melts at a much higher heat. Protosulphate of iron is added to a solution of lead in nitric acid, in such quantity that the resulting solution shall not be very concentrated. Professor Jacobi obtained films of *brass* by preparing solution of cyanide of potassium, and throwing in copper, from a positive plate of copper, and then zinc from a positive plate of zinc; after a certain time brass was given off.—I have repeated Jacobi's experiments, and made many hundred original ones, with very various solutions, to discover whether it were possible to obtain a solution that should *continue* to give off brass. I have obtained deposits of most brilliant brasses, but all the solutions yet operated upon have failed to retain their properties beyond a day or two: new chemical combinations occur.

140. *Electrolysis of fused compounds*.—Mr. Arthur Wall has a patent for purifying iron-ore from sulphur, phosphorus, and other such elements, by applying a powerful voltaic current to the metal while in a state of fusion, either when it is in the smelting furnace, or while it is in the moulds; and he prefers continuing

the current until the metal is solidified. In reference to these experiments, Dr. Ure is understood to have stated that a current was passed through a rod of soft iron, at a moderate heat, and, in a few hours it was converted into steel.

141. Mr. Napier has patented a process for reducing copper from its ore by the aid of an electric current. Native sulphuret of copper, for instance, is roasted in the usual way, and is then melted with lime and soda as fluxes; the pot is now so connected with a battery as to be the negative pole, or place for receiving deposits; and a plate of iron connected with the positive pole is thrust beneath the surface of the fluid mass; a solid mass of copper is soon found deposited on the inner surface of the pot, the quantity of which is stated to be more than a dozen times that of the chemical equivalent of the electric action.

142. Mr. Parker has a patent for plating and gilding by means of fused iodides, chlorides, and phosphates of the metals. As an example, he takes 6 lbs. of chloride of silver, fused in a silver or an enamelled iron vessel; when fluid, he immerses in it the article to be plated, which is in connection with the negative end of the battery, and a plate of silver connected with the positive end: to increase the quantity of fluid, he sometimes adds to it from 3 to 10 lbs. of iodide of potassium, or even the iodide of mercury or copper, in the proportion of 1 or 2 lbs.

For a gold fluid he takes 20 oz. of iodide of gold and 80 oz. of iodide of potassium or sodium, which he subjects to similar treatment, using, of course, a gold instead of a silver plate.

143. Mr. Ritchie has a patent for extracting copper from its ore by a very simple voltaic arrangement. He dissolves the calcined copper ore in dilute sulphuric acid, and places the solution in a large rectangular vessel; on the upper surface of this, he pours a mixture of two parts water and one saturated solution of sulphate of

iron, taking care that mixture does not take place with the lower liquid; he then places an iron plate as a generating metal in the iron solution, and a plate of lead in the copper solution to receive the deposit, connecting the lead and iron with a wire.—It is also stated that, by this process, galvano-plastic objects may be easily obtained on a large scale.

144. *Magneto-electro Machine*.—We are here called upon to notice another means of obtaining electric currents, inasmuch as it has been successfully applied by Mr. Woolrich of Birmingham, to gilding and plating. A magnet has the property of generating electric currents in all metals that are in *motion*, within the sphere of its influence; but only *while* they are in motion. By proper adjustment, these effects may be exalted. In practice, powerful horse-shoe magnets are employed, and great lengths of silk-covered copper wire, wound upon bobbins with iron cores, are made to revolve in front of the magnetic poles, by the action of a small steam engine. Arrangements are made to intercept the currents at the ends of the coils, and to convey them into a trough containing the metallic solution. By sliding a keeper along the magnet to various distances, the force of the current is modified. A single machine will reduce five ounces of gold per hour. A large machine was constructed that was calculated to have deposited twenty ounces per hour; but it is thought to have been damaged by other experiments. The steam power for driving twenty such machines is stated to cost only 15s. per week—the wear and tear is small. But all things considered, the Messrs. Elkington have found it more profitable to continue the employment of the Voltaic Battery in their extensive works.

Dr. Braun is employing, it is said, one of these machines at Rome, for producing electrotpe copies from casts of the works of art in that city, as referred to hereafter (§181).

II.—DEPOSITION OF THE OXIDES OF METALS ON METALS.

145. *Metallo-chromes*.—Hitherto we have been considering the deposition of *metal* on metal; it remains to give a familiar description of the mode of depositing *metal in union with oxygen, i. e. a metallic oxide* on metals. The most beautiful experiments of this kind are those described by Nobili,* and recently repeated and considerably modified by Mr. Gassiot.† The productions are known by the name of *metallo-chromes*. A saturated solution of acetate of lead is prepared, and poured into a shallow vessel, in which has been placed a highly-polished steel-plate. A wire from the *positive* end of a series of three or four Daniells, is made to touch the plate. Then, if another wire from the *negative* end of the series is held in the solution, over the plate, a small tinted circle makes its appearance on the polished surface beneath the wire, and rings of colour of the most brilliant hues rise from the centre and expand to the circumference. The colours commence with silver-blond, and progress onwards to fawn-colour, and thence through various shades of violet to the indigos and blues; then through pale blue to yellow and orange; thence through lake and bluish lake, to green and greenish orange, and rose orange; thence through greenish violet and green, to reddish yellow and rose lake, which is the highest colour on the chromatic scale.

146. Coloured figures of varied character are obtained by modifying the shape of the electrode connected with the negative end of the battery; using, instead of a point, a slip of metal, a disc, a ring, a convex or a concave circle, a cross, or other pattern. By the employment of a large disc, and small steel plates, and by very careful manipulation, a uniform tint may be given to each plate, and the chromatic scale of forty-

* Scient. Memoirs, Vol. I. Art. 5.

† Proceed. Elec. Soc. Dec. 17, 1839, 4to.

four colours may be obtained. For this purpose each experiment must be timed by a pendulum, and one second being given to the first plate, the duration for the rest must increase by a second for each. It is absolutely essential in operations of such extreme delicacy that all the plates be of the same thickness, so that, when adjusted to their position, they may remain at the same distance from the disc. Many more than forty-four specimens will be produced, which must be placed in order, and the similar tints rejected. The spoiled plates are cleaned with fine emery paper.—The best metallo-chromes are obtained by cutting a star or other pattern in card, and placing the pattern on the plate, beneath a convex or a concave disc.

The colours arise from the very thin films of oxide of lead, that are deposited on the steel plates: and are due to an analysis of light, similar to what occurs in a soap-bubble,* or in the film of air between a lens and a plate of glass, closely pressed together. No practical use had been made of these films.

147. *Deposition of Oxide of Lead.*—M. Becquérél has described† a means of coating metals with oxide of lead and oxide of iron, for the purpose of protecting them from the action of the air. He uses a *potash solution of lead*, which is prepared by dissolving 200 grammes‡ of caustic potash in two litres§ of distilled water, and adds to it 150 grammes of protoxide of lead, —the *litharge* of commerce.—It is boiled for half an hour, and, after being allowed to settle, is diluted for use with its volume of water. Some of the solution is

* The best mode of making a soap-bubble is to place a piece of soap, about as large as a pea, in a six-ounce vial, one-third filled with water; the vial is to be then placed in a vessel of water, and the water to be boiled. When the vial gives off steam pretty freely, it is to be corked, and then removed and sealed immediately. A horizontal film of soap may at any time be made by shaking the vial.

† Vide "Comptes Rendus," 3rd July, 1843.

‡ A gramme = $15\frac{1}{2}$ gr. troy.

§ A litre = 61 cub. in.

poured into a porous tube, which is placed in a vessel containing water acidulated with one-twentieth its weight of nitric acid. The nitric acid contains a platinum plate, connected with the negative or zinc end of a single cell of Daniell's battery; and the article to be coated with oxide of lead, as for instance, a plate of iron is placed in the solution of lead, and connected with the copper of the battery. In a few minutes the plate is covered with a coating of peroxide of lead, which arises from the union of the oxygen with the protoxide of the solution. The adherence is very strong, and if the article has been well prepared (§ 116, &c.), will sustain the action of the burnisher. The colour of the deposit is black with a brownish tinge; if the action is allowed to continue, it assumes the tint of yellow ochre. The liberation of hydrogen on the platinum plate is a sign that things are going on well. The solution must not be used to exhaustion, but be replaced by fresh, after perhaps a dozen hours of action.

148. *Deposition of oxide of iron.*—An ammoniacal solution of iron is used for obtaining a deposit of the peroxide. A hot solution of protosulphate of iron is prepared, and placed in the receiver of an air-pump, to abstract from it all air; a solution of ammonia is likewise deprived of air, and a little more than is sufficient to dissolve the protoxide of iron is poured into the former solution. This solution is used in the same manner as that of lead, described in the preceding paragraph, namely in a diaphragm decomposition cell; but care must be taken to keep it covered from the air, which has so great a power, on account of the oxygen it contains, of converting the protoxide into a peroxide. A few minutes suffice for the operation. The deposit of peroxide is of a brownish red colour, having somewhat the appearance of precipitated copper; if the action continues, the colour becomes darker, and finally it is deep violet. The oxide will endure the burnisher.

If the action is carried on at an elevated temperature, the adhesion is greater, because the contraction of the expanded metal binds the film more closely. The use of the diaphragm in these operations is to prevent the solution from becoming exhausted ; for if the experiment were carried on under ordinary circumstances, the deposition of *metal* at the one electrode, and *oxide of metal* at the other, would very soon deprive the solution of its contents.

III. ELECTRO-ETCHING.

149. The results hitherto treated on, have been (with the exception of the deposition of the oxides,) all obtained at the *negative* metal ; but there is a class of results of no inconsiderable importance to be obtained at the other terminal.

The plates of copper, in the decomposition cell, in connection with the copper of the battery, have been described as combining gradually with the oxygen released there, and being eventually consumed ; so likewise the plates of silver or gold, which occupy the same relative position, are in a similar manner consumed. But as the varnish, (§ 31.) placed on moulds, effectually shields the parts protected by it, from the effects of electrolytic action, so also may the copper plates, or the plates of any metal connected with the positive end of the battery, be protected, and the *destructive* action localised at pleasure.

150. If, for instance, plates of copper be covered on any part of their surface with a stratum of varnish, that part will be excluded from the line of action, while all else is being consumed. Advantage has been taken of this, by coating plates with proper composition and then tracing through it any design, of which an etching is required. The plate in this condition is submitted to the action of the nascent oxygen, and the surface is readily and effectually etched. There is some superiority too possessed by this method, over the ordinary

etching by the use of nitric acid ; for the operation can be conducted with considerable regularity ; it can be rendered a slow or a speedy process ; and the result can be taken out, from time to time, to be examined, and can be re-submitted in a moment. In fact, of so much importance has this mode of etching been deemed, that it is already one amongst the many applications of this principle for which a patent has been obtained.

151. *Process of electro-etching*.—Take a burnished copper plate, and solder to it a stout wire : heat the plate, and rub its surface with etching ground,* wrapped in silk ; be careful to obtain an even coating ; then smoke the covered surface over the flame of a candle. Varnish the back of the plate, as well as the wire, with shell-lac. Trace the design through the etching ground with a fine point. This done, place it in a decomposition cell, and connect it with the copper of a Daniell's or other cell, placing opposite to it a plate of somewhat similar size ; after the lapse of ten minutes remove it, and "stop out" the fine parts with Brunswick black ; return it to the decomposition cell for a second ten minutes ; and again stop out the half tints ; again submit it to action for ten minutes, and the operation is complete. Remove the etching ground by means of heat, and a perfect engraving will be found on the plate. The *exact* duration of the several operations, as well their number, must be regulated according to circumstances. Electro-etching is an interesting experiment for the lecture table. At the commencement of a lecture, I have submitted a plate to electric action, and before the hour has expired, have distributed proof impressions.

152. An etching ground of gold may be applied by submitting a copper plate well varnished on the back, to the action of an electric current passing through a

* Etching ground consists of asphalte, wax, black pitch, and Burgundy pitch.

solution of the cyanide of gold. When a perfect coating is obtained, the plate is removed; and the design is etched with a fine point through the *gold film*. The plate is then submitted to the action of the battery, as before; and as the oxygen, released there, combines with the *copper*, but not with the *gold*, the design is permanently etched.—The process of etching is very speedily effected; and must, therefore, be very carefully attended to, lest, by proceeding too far, the plate be spoiled.

153. *Electro-etching Daguerriotype plates*.—In the description last given, the *artist's* hand must first trace the design, before the electric force will engrave for him; but Mr. Grove has described a process,* by which the pencil of nature does *all* the work. He has taken Daguerriotype plates,—those beautiful productions “drawn by light,” and, having submitted them to the still further operation of Nature's laws, has succeeded in “engraving by electricity.”

154. Though this process has not been perfected, so far as to produce plates fitted in *all* respects for the printer, yet, as it is a very important and instructive application of the subject on which we treat; and, as it furnishes, though not for the *printer*, yet for the *electrotypist*, plates from which *he* can obtain *perfect* impressions, and these to any extent, it claims especial notice in this treatise.

155. *Nature of Daguerriotype Pictures*.—The dark portions of these pictures are considered to be *silver*, and the light portions *mercury*; and hence, if they are placed in a solution, whose liberated element shall act on *one* of these metals, and not on the *other*; or if they are submitted to a solution, the liberated element of which combines *more* with one than the other, the result will be an etching.

156. Hydrochloric acid, diluted with half its bulk of water, has been employed. From hydrochloric acid,

* Vide Proceed. Elec. Soc., vol. i. p. 94. Aug. 17, 1841.

hydrogen is released at the negative plate; and the great object is to dispose of it regularly, and as speedily as may be; for, if any hydrogen adheres to the surface of this plate, the surface of the plate to be etched, where it is *opposed* to this, will furnish an irregular result. The best plates for parting with the nascent hydrogen, are platinized silver, or platinized platinum. The distance between the two plates, (which are, of course, placed parallel,) should be about the fifth of an inch, which is *near enough* to ensure uniformity of action, and *not so near* as to allow the escaping hydrogen to interfere with the result.

157. In a process so delicate as that of etching out the microscopic delineations on these plates, due regard must be paid to the relation between the size of the generating pairs and the size of the plates themselves. The best mode is to have the generating pair and the decomposing pair of *one size*, or nearly so; and, as the solution employed will give up its elements with a feeble current, one generating cell is enough. Prof. Grove used a single pair of the *nitric acid battery*; but any other will produce the desired result. The *time* of action depends on the nature of the generating cell employed. With the nitric acid battery, (which is very energetic in its action,) the effect was produced in from 25 to 30 seconds. With other arrangements it will be longer; and, possibly, as it is accomplished more slowly, the result will be more definite; and the experiment will be less liable to fail.

158. Having determined these several points, and shown the reasons on which they are based, (and I always wish to furnish *reasons* for all that is done; for when a man acts by mere directions, and arrives at ends he knows not *why*, I am well assured that his interest in the subject will soon be dissipated, and his path, instead of being pleasing and bright, will be dull and gloomy;) the next arrangement is to prepare a wooden frame with grooves into which the two plates,

viz., the Daguerriotype * and the platinized plate can slide, so as to remain firmly fixed in the required position. This frame is then immersed in the solution, and contact is made with the generating cell by touching, with the ends of the connecting wires, the edges † of the plates ; and retaining them in contact for the given time. “The plate is then removed, and well rinsed in distilled water, and if the silver be homogeneous,” ‡ will “present a beautiful sienna-coloured drawing of the original design, produced by a film of the oxychloride § formed ; it is now placed in an open dish, containing a very weak solution of ammonia, and the surface gently rubbed with very soft cotton, until all the deposit is dissolved ; as soon as this is effected, it should be instantly removed, and plunged into distilled water, and carefully dried. The process is now complete, and a perfect etching of the original design will be observed ; this, when printed from, gives a *positive* picture, or one which has its lights and shadows as in nature ; and which is in this respect, more correct than the original Daguerriotype, as the sides are not inverted : printing can therefore be *directly* read ; and in portraits thus taken, the right and left sides of the face are in their proper position.”—“There is, however, *ex necessitate rei*, this difficulty with respect to *engrav-*

* This plate must be well varnished on its back and edges.

† A small portion of varnish is removed from the Daguerriotype for this purpose.

‡ “It is very necessary that the silver of plates subjected to this process be homogeneous. Striæ, imperceptible in the original Daguerriotype, are instantly brought out by the nascent anion (or element liberated from the solution at the positive pole) ; probably silver, formed by voltaic precipitation, would be found the most advantageous.”—PROF. GROVE. This extract, illustrated as it was by the condition of the prints from some of the etched plates, indicates that the application of electro-plating, before described, (§ 137) will eventually be found of some service.

§ Oxygen from the water, and chlorine from the acid, are released at the Daguerriotype plate.

ings from Daguerreotypes ; if the plates be etched to a depth sufficient to produce a good impression, some of the finer lines of the original must inevitably run into each other ; and thus the chief beauty of these exquisite images be destroyed. If, on the other hand, the process be only continued long enough to leave an exact etching of the original design, which *can* be done to the minutest perfection, the very cleaning of the plate by the printer destroys its beauty ; and the molecules of the printer's ink being larger than the depth of the etchings, a very imperfect impression is produced."*

159. But though these mechanical difficulties exist with respect to *printing* from an etched plate, yet the *etching* is perfect. The action of the liberated elements has produced, perhaps, the most delicate piece of workmanship ever seen ; and though many practical difficulties will ever exist against successfully printing from such plates, yet the electrotypist possesses the means of multiplying the most faithfully and elaborately executed among them, with undeviating certainty ; and of obtaining in metal as many perfect copies of the original as he may think fit to take. "To give an idea of the perfect accuracy of these, I may mention that in one I have taken," writes Mr. Grove, "on which is a sign-board, measuring, on the electrotype plate $\frac{1}{10}$ th by $\frac{6}{100}$ ths of an inch, *five* lines of inscription can, with a microscope, be distinctly read."

160. I can conceive, therefore, that among those into whose hands these pages may fall, are many who will value this discovery which furnishes a means of multiplying readily these treasures of ART, I was about to say ; and possibly *art* is the fittest designation to give to this process which has arisen at the magic touch of science. It is true no living *artist* can produce pencillings so true and faithful, but science has called into action the finger of nature, who is ever faithful and ever true ; and has inscribed upon her productions,

* Vide Proceed. Elect. Soc. p. 98.

not the words "drawn by Landseer, and engraved by Cousins," but "drawn by Light, and engraved by Electricity."*

161. *M. Fizeau's Process.*—M. Fizeau has been most successful in engraving Daguerréotypes. He inserts the plate in a mixture of nitric, nitrous, and hydrochloric acids, by which means the black or silver parts of the picture are eroded: he then washes out the chloride of silver thus formed with ammonia, and again immerses the plate in the acids, repeating the process several times. A certain depth of etching is thus produced. He then rubs linseed oil on the plate, and washes it off so, that the parts in relief may be still exposed; he now gilds these parts by the electro process, and afterwards removes the oil by caustic potash; this being done, he bites in the hollow parts with nitric acid, and so augments the depth at pleasure. Now, as silver would soon wear out in the press, he coats the whole surface with copper by electric deposition, and thus prepares the plate for use; and when one surface of copper commences to wear, he removes it by chemical means, and supplies its place with a fresh deposite.

162. *New Mode of Etching.*—Dr. Pring has described † another mode of etching. A polished steel or other metal plate is connected with the positive end of a series of four or five, a good coil of coated copper wire being interposed between the plate and the battery. The other wire, guarded by glass or other insulator, is held in the hand and employed as an etching tool, when any device may be drawn. The magneto-electric machine will also furnish electricity for this mode. The plate may be reversed and connected with the negative end to vary the experiment. Various wires may be used. No solution is employed; it is therefore

* Vide Prof. Grove's paper.

† Vide Phil. Mag., Aug. 1843.

not included in our present art, being mentioned here as a curious fact.

IV. APPLICATIONS OF ELECTROTYPE, &c.

163. *Patents.*—In reviewing the patents taken out, (and there are not a few) I have felt some degree of difficulty in tracing the features by which the right of one is distinct from the right of another; and have almost doubted whether many of the patents are not based rather upon the nature of the *moulds*, than of the *power* employed. To one is allowed the peculiar privilege of making a wax model of a *stewpan*, and depositing copper upon this; to another the peculiar right of making the model of a *seal* by uniting some *printer's type*, and depositing copper upon this. I shall best succeed in conveying an idea of the extent to which this art has been patented, by extracting from the several specifications the general summaries on which the claims are based. And I doubt not that my readers will be somewhat surprised, when they find how the *principle* of electro-chemical decomposition,—for it is but a general *principle*,—has been seized upon and appropriated.

164. One has accomplished certain “improvements which have for their object the coating or covering manufactured articles composed of wrought or cast iron, lead and copper and its alloys, with copper or nickel; such coating being effected by means of galvanic electricity.” Nor does he “confine himself to any particular arrangement of apparatus, but claims the mode of treating manufactured articles, of the metal and alloys above stated, so as to obtain a permanent coating or covering of copper or nickel.”

165. With respect to plating, patentees claim “the use of a solution* of silver, in prussiate of potash,† or

* It is stated “that it will be found necessary to add from time to time a fresh supply of the oxide to the solution, in order that it may be kept saturated with that salt.”

† Or rather cyanide of potassium. Vide § 95.

other analogous salt, or in pure ammonia, in combination with a galvanic current ;” and “ the use of a solution of silver in acid, so as to constitute a neutral salt, in connection with a galvanic current ; the articles in this (the latter) case having been previously coated with silver.” Under the head of gilding, is claimed “ the use of a solution, for the purpose of gilding, formed of oxide of gold, dissolved in prussiate of potash or soda, or any other analogous salt, and combining the action of a galvanic current with the use of a salt of gold as above, preferring the solution of gold formed by dissolving the oxide of gold in prussiate of potash ; and, further, the patentees claim, with reference to the two last heads of their invention, the application of a galvanic current, in combination with solutions of gold or silver for coating or plating with gold or silver, whether the articles to be so coated are formed entirely of metal or only partly so.”

166. The same parties prepare surfaces of iron to receive a coating of copper or other metal, by connecting them with a piece of zinc and placing them in acid, so as to form a voltaic pair ; “ after a short time the scales and dirt will fall from the iron, leaving its surface perfectly clean and bright ;” and fit to receive a coating of copper, and then one of silver or gold.

167. The right is claimed of etching on *iron or steel* by the electrolysis of a solution of common salt, and an iron or steel plate ; on *silver*, by a solution of sulphate of soda or sulphate of silver, and a silver plate ; on *gold*, with hydrochloric acid, and a gold plate ; on *copper*, sulphate of copper and a copper plate ; nor do the patentees limit their claim to the metals named, but “ claim the use or application of voltaic electricity for engraving on metals generally ;” and hence, I presume, within this COMPREHENSIVE clause is included the etching of Daguerreotype plates ; although the latter process was not discovered until months after the patent was enrolled.

168. Another application of the art is to form rollers of copper for printing or embossing calicos, &c., by making a model of a roller, and, after rendering it a conductor by any of the ordinary means, depositing copper upon it;* also for thickening old cylinders, rollers, &c., for the same purpose; and for filling up portions of patterns that are to be obliterated.

169. Other applications of this process are described: "1st, in the production of a printing, embossing, or impressing metallic cylinder, plate, or block, having a device or pattern formed thereon, suitable for the above purposes; such device or pattern constituting *one perfect* or *connected* design, produced from an originally engraved or otherwise executed *portion* of the said design; 2nd, in a mode of *joining* together engraved or otherwise executed metallic plates, so as to form *one connected* surface; 3rd, in obtaining an *extended* plain surface to an engraved metallic plate, whereon a continuation of, or an addition to, the subject already formed may be engraved; 4th, in certain modes of producing *suitable* surfaces, as aforesaid, such modes not requiring the ordinary original process of engraving;† 5th, in a mode of producing surfaces, as aforesaid, such surfaces being suitable for printing, or printing or embossing in various colours;* 6th, in the application and use of dies, formed by the agency of voltaic electricity, for the purpose of embossing or

* This is merely a variation in the *form* of the mould.— (§ 163.)

† A flat metal surface is covered with varnish; the design is traced by removing the varnish; the whole is then covered with plumbago, (§ 39.) or rendered conductible by other means; and is placed as a mould in connection with the battery; or a lithographic stone is prepared and treated in a similar manner; or the design is punched in sheet-lead, and this is united to other metal, and then deposited upon.

* Two or more moulds, according to the number of colours, are obtained from the *same* original; and from each are removed those portions which are *not* to be printed by the colour to which it will be confined.

impressing horn, hoof, or tortoise-shell, in the manufacture of buttons; 7th, in the mode of mounting or attaching seals, bookbinders' tools, or *other such instruments* used for impressing, such instruments or tools being produced by the agency aforesaid; and lastly, in a mode of producing seals for impressing on wax or other such substances."

170. The object of another "*invention* is to produce pipes, boilers, stewpans, or other vessels of copper, through the agency of Voltaic Electricity;" by depositing copper on moulds of "clay, wax, plaster, or other like substances; or of lead or other metal, fusible at a lower temperature than copper." Another part of the invention relates to the joining together of several pieces, so as to form vessels; and by which means stop-cocks, or other such parts, may be added to boilers, &c., formed by the above process."

171. The above is by no means a complete abstract of patents, as our readers will have themselves discovered from many other processes that have been presented to them in the course of this work. But we must devote the space that remains to a few subjects that have not a place elsewhere.

172. In the preceding pages, I have dwelt on the copying of medals and plaster medallions alone. Enough, however, has been said to render the subject familiar, and to enable those who are successful in copying the small objects here treated of, to carry their experiments to any extent. Busts, statues, vases, may, by proper application of the principles laid down, be as readily coated with copper as the small wax moulds. (§ 32.) Yea—almost anything, to which a coating of plumbago can be given, may serve as a mould on which to deposit the metal. Gutta Percha, a new gum, which becomes plastic at less than 212° Fahrenheit, and hardens on cooling, will be often found a most convenient material for moulds (§ 42). With no credit to my discernment, I might devise a thousand instances in which this

art will be available in the common concerns of life; but rather leave the merit to him who shall actually introduce it into these several spheres. It may be found available in protecting from the effects of weather the busts and statues, which are introduced in ornamental gardening; and which are often, for the sake of economy, made of plaster of Paris. They may be saturated as described elsewhere (§ 40.); covered with plumbago (§ 32.), and placed within a large vessel whose sides are covered with copper, and then by means which must now be familiar to the reader, a deposition of copper may be formed on them: this can be bronzed by the simple application of the blacklead brush; and thus a slightly and permanent exterior will be produced. —By the same means small and valuable wax figures may be preserved; the surfaces of these are of themselves very liable to crack, and fall off in chips. A *thin* covering of copper, without in the least degree affecting the fineness of the workmanship, will preserve it. Busts and statues may be made in solid electrotype metal, by first coating a bust with thin copper, then embedding the whole in plaster or cement, afterwards breaking away the original bust, and finally making the mould that remains serve as a decomposition cell.

173. ELECTRO-TINT, OR GALVANOGRAPHY.—Another form of deposit has been termed electro-tint. It consists in painting on white metal with etching ground or varnish:—the several shades are obtained by the relative thickness of the layers of varnish: the whole is then plumbagoed; and the deposit obtained on it is used as a plate to furnish prints. Prof. Von Kobell, after obtaining a plate, examines a proof; and if too faint, he makes a mould of the plate; and having obtained a deposit, which will be similar to the original painted plate, he puts varnish on the parts which gave impressions too pale, and obtains a second deposit on this, which when removed will give prints of a better character.

174. Engraved copper plates may be readily multiplied by electrotpe. The battery must be in proportion to the size of the plate, and the plate must be used in lieu of the moulds. Sometimes the copper deposit will adhere so strongly as to resist all attempts to remove it. This may be prevented by a very easy process.—Before the plate is used, heat it and rub bees' wax over the surface ; continue the heat, and by the application of soft cotton, rub it perfectly clean from the wax ; or the plate may be rubbed with blacklead in lieu of wax. In either case it may then be used without fear of adhesion. The deposit obtained on it is to be removed, and used as a mould, from which many copies may be taken equal, in all points, to the original. The engraved plates of the recent *Survey of London* are being thus multiplied.—Sometimes moulds of medals and casts are made from originals in Electrotpe copper.

175. *Glyphography* — is another application. A smooth copper plate is blackened by sulphuret of potassium, and is then coated with an etching ground, through which a design is traced. The high lights are now built up of non-conducting materials, so as to prevent their printing ; the whole is coated with plumbago, and an electro-copper-plate is formed from it : the copper plate is afterwards soldered on a block of wood, and is used as a wood-cut ; it is called an *electro-glyphographic cast*. Or this plate, after etching, has a plaster cast taken from it, and from this the high lights are cut out ; it is then oiled, and a second cast is taken, from which a stereotype copy is to be made. This is called a *stereo-glyphographic cast*.

176. *Metallic cloth*—is prepared by Messrs. Elingtons, for various purposes. On a surface of copper is attached very evenly, stout linen, cotton, or woollen cloth : the copper is placed in a solution of copper, or other metal, and is connected with the negative pole of the battery : a sheet of copper, or other metal, as the

case may be, is placed opposite, and in connection with the positive pole of a battery. Decomposition takes place, and the metal, in endeavouring to reach the metal plate, insinuates itself into the interstices of the cloth, and forms a perfect metallic sheet.

177. *Purity of sulphuric acid.*—As the great object of writing this treatise is to simplify the various stages of the process, I must not leave unnoticed a fact that has been pressed upon my attention, one which is of great practical importance,—the necessity of employing *pure* sulphuric acid; I mean, so far pure, as to be free from *nitric* acid. Very commonly a small portion of nitric acid is present, and this operates in a most destructive manner upon the zinc, defying all care and trouble in amalgamation: for it attacks some of the mercury, and leaves portions of the zinc exposed, giving rise to an amount of local action to no trifling extent; indeed it is the serious objection to the use of the platinized battery: and has caused it to be rejected by many manipulators. This will explain the cause of amalgamation's failing far more effectually than the assumption of the impurity of the zinc. The latter is well concealed by the mercury; but the nitric acid undermines the other precautionary means, and militates most effectually against the permanent preservation of the zinc.

178. *Test for nitric in sulphuric acid.*—The presence of nitric acid may be determined by the following simple and effectual test.—Apply heat to a Florence flask, containing sulphuric acid, with which has been mixed some sulphate of indigo; should the blue colour disappear, nitric acid is present; should it remain, the acid is good and fit for use.—Besides exciting the batteries with the pure acid, it is also requisite to employ the same acid in the process of amalgamation. When these precautions are taken, the common rolled or cast zinc may be employed with impunity, and a *perfect*

action will be obtained. It is rather a difficult matter to get rid of the nitric acid.

179. In reference to electrotype medals and other works of art produced in moulds taken from the originals, it may be as well to remark that there are two methods of giving them a silver or a gold surface by electric deposition; either by making the medal according to the instructions given in the First Part of this work, and then gilding or plating it; or by preparing a good and clean mould, (§ 28,) and depositing in it a certain quantity of silver or gold, and then backing it up by the deposition of copper. The best electrotype medals are produced in this way.

180. *Copying Busts, &c.*—It may not be out of place to add here the method pursued for copying busts or statues from *wax* originals. The original is covered in the usual way (§ 32.) with plumbago; it is then placed in the copper solution of a decomposition cell, (§ 56.) and is acted on until a moderate coat of copper is obtained: it is now removed and embedded in plaster of Paris; the wax is melted out, and the interior well cleaned with a hot ley of potash or soda. It is then inverted and filled with a solution of the metal which is to be deposited; and in the solution is placed a sheet of the same metal, as in the ordinary arrangements. The theory of this operation is self-evident; but in practice, especially on small articles, a difficulty presents itself, to guard against which requires no little care. The action occasionally ceases without any apparent cause; and for days, although all things seem in order, no appreciable deposit takes place. This can only be obviated by cleaning the positive metal and greatly reducing the action. The effect is due to phenomena too complex to be detailed in the present treatise.

181. It is very gratifying to observe the late important application of the art that have been made by the Elkingtons. Dr. Braun has been for some years in Italy,

and has obtained electro-type moulds from casts of some of the finest sculptures ; these moulds are now the property of Messrs. Elkington, who intend to publish copies obtained by their means ; and not only so, their intention is also to multiply the choice works of modern artists by similar means ; and thus to place within the reach of the man of taste, at a comparatively moderate cost, faithful representations of the choicest works of the chisel, which could not otherwise be obtained except at great cost, and, in the majority of instances, could not be obtained at all.

The Messrs. Elkington have already commenced publishing, on a reduced scale, genuine copies of portraits of the men of classic antiquity, the moulds of which have been obtained from the Museo Borbonico, at Naples, and from the Lateran Museum.

182. I have not space to make any lengthened comments upon the extensive applications of electrotype. I can fancy that scarcely one will read this treatise with attention, and reflect on the uses to which the art *has been* applied, without figuring to himself many others to which it *may be* applied. The science on which the whole of what we have treated is based, reminds one of that little cloud, dimly seen at first in the distance, no bigger than a man's hand, which gradually develops itself, until it enfolds within its spacious mantle the whole of the visible face of nature. Every day is bringing fresh evidence of the vast extent of the operations of electricity ; although each fresh acquisition of knowledge only teaches us how *little* we really *know*. Scarcely do we elucidate one series of problems, than another, and another, and another, presents itself to our earnest gaze ; and we are compelled, in summing up the results of even our most successful labours, to confess with the great philosopher, that we are like children on the sea-shore, who pick up occasionally one pebble of better value than the rest.

Dec. 1, 1849.

CHARLES V. WALKER.

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